OBSERVATIONS OF INTERNAL LEE WAVE GENERATION

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LONG-TERM GOAL

My interests are in oceanic phenomena that contribute to stirring and mixing ranging from the meso- to the microscale (10 km - 1 cm), with emphasis on their interactions. These include internal waves, tides, potential-vorticity-carrying finestructure, turbulence, double diffusion, bottom topography and surfacing forcing. Parameterization of the impact of these 'subgridscale' processes on larger scales through dynamical understanding is the ultimate goal.

OBJECTIVES

My recent focus has been on understanding how meso- and finescale flow fields interact with complicated topography such as seamounts, canyons, ridges and rough bathymetry. Mixing in the stratified ocean interior is too weak to close the meridional thermohaline circulation of the deep ocean (Ledwell et al. 1998). I am exploring whether topographically-enhanced turbulent mixing is sufficiently large to do the job, and to understand the mechanisms responsible for its generation.

APPROACH

During May 1998, I participated in a cruise to the Virginia continental slope in collaboration with Drs. Kurt Polzin, John Toole and Ray Schmitt (WHOI). This observational program was designed to characterize the internal wave and turbulence climates above an undulating slope of 1-km wavelength ridges and gullies. This topography, in combination with low-frequency alongslope flows associated with topographic Rossby waves, was thought to be suitable for generation of internal lee waves. I conducted surveys with expendable current profilers (XCPs) and expendable CTDs (XCTDs) to obtain 3-D snapshots of velocity, temperature, salinity and vertical displacement over the full water depth. These measurements complement the temporal sampling of the other investigators' moorings and profiling work by providing detailed horizontal/vertical structure in the water column along and across a ridge-gully pair.

WORK COMPLETED

The cruise was successful. High-quality data were collected along three sections: one along the slope transecting a ridge-gully pair, one crossing the slope along a ridge and one crossing the slope along a gully. At each of 25 stations, 4 XCP/XCTD pairs were deployed over a 12-hour period to allow isolation of tidal from higher- and lower-frequency fluctuations.

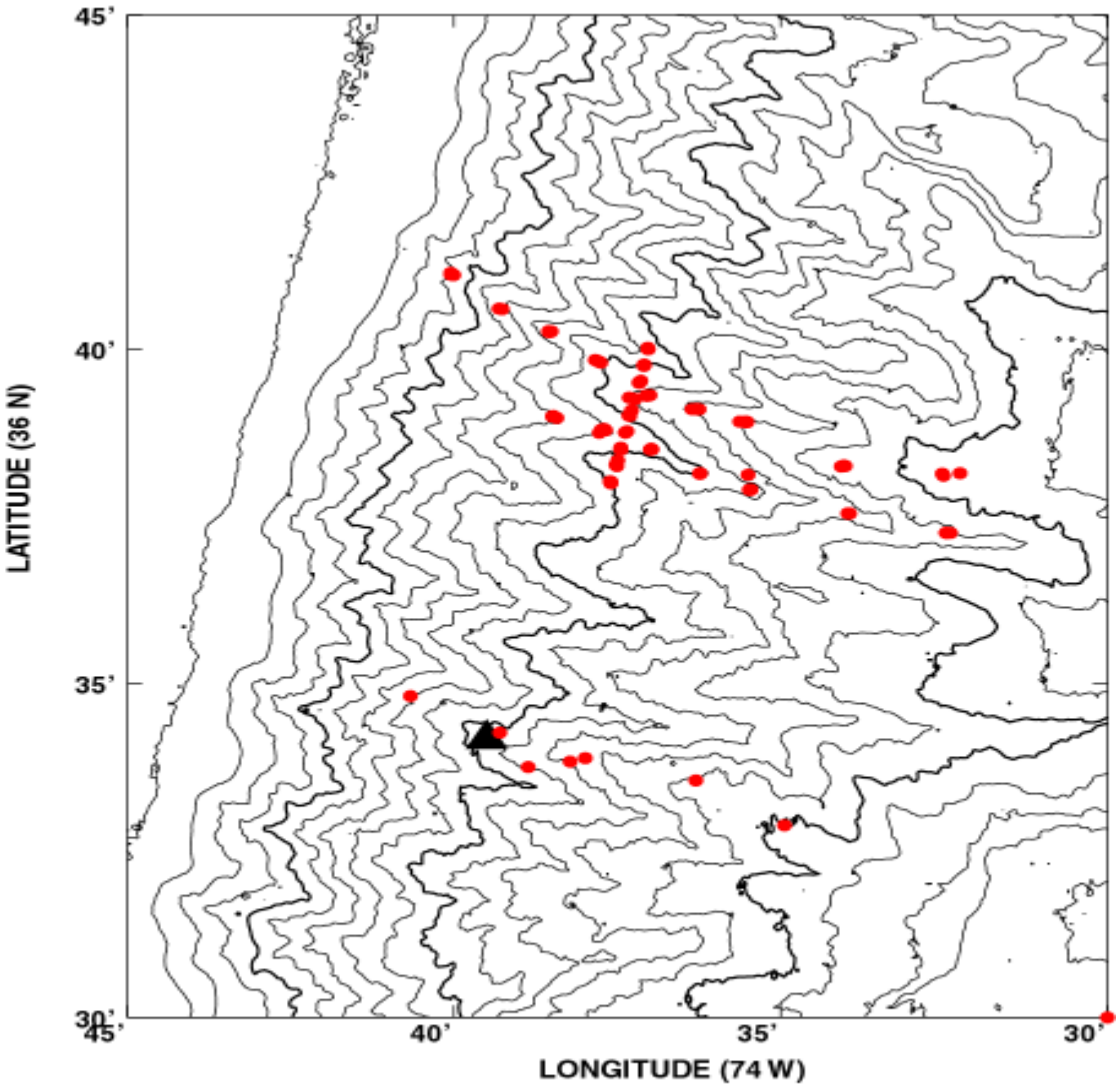

Fig. 1: XCP/XCTD sampling on the continental slope off Virginia during TWIST. Sampling consisted of a preliminary cross-slope section near the site of the current-meter mooring array (triangle), and sections along slope, along ridge and along gully to the north. These latter sections were reoccupied four times in 12 hours.

All data have been acquired and processed. XCP velocity profiles have been made absolute by correcting them with GPS-referenced shipboard ADCP profiles. This coming biennium, I will be estimating vertical displacements from the density profiles and calculating the horizontal energy-fluxes <v'p'> to determine whether the slope and shelf are sources or sinks of internal gravity waves.

This past year, I have also revised and submitted papers from the Ph.D. theses of two students who have left the field. Dr. Joanna Muench conducted a theoretical investigation of internal wave interaction with the equatorial deep jets. Dr. Haili Sun revisited the internal wave/wave interaction problem. Unlike Henyey et al. (1986) she included interactions with internal wave vertical divergence as well as vertical shear. I presented a talk about Dr. Sun's work at the 1999 'Aha Huliko'a workshop on Internal Wave Modeling.

RESULTS

The data show strong vertically fluctuating signals. Alongslope flows across the topographic undulations are weak in the bottom few hundred meters, putting the near-bottom flow into a regime where bottom-trapped motions and turbulent boundary layers are expected rather than internal lee wave generation. Signals are no larger than those found above other rough topography. Dr. Muench's thesis showed that deposition of internal wave momentum at critical layers is sufficient to maintain the jets. Dr. Sun's found a finescale parameterization for turbulent mixing consistent with the work of Polzin et al. (1995).

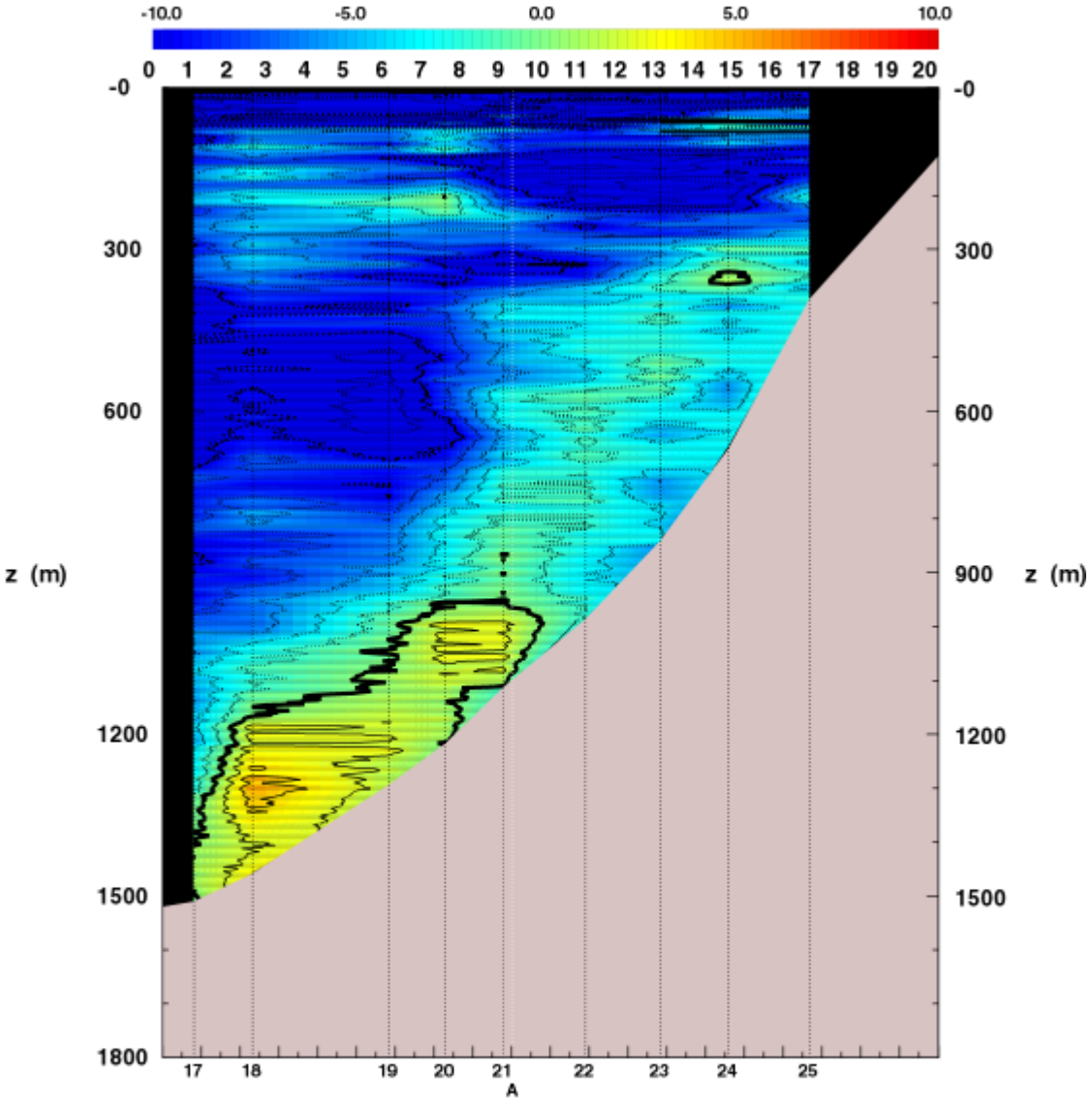

Fig. 2: Along-gully section of 12-h averaged alongslope velocity <v>. Southward flow is found in the upper water column, particularly in the upper 100-m. A 300-m thick layer of weak counterflow occurs above the bottom. Similar but thinner counterflows are found above the ridge.

IMPACT/APPLICATION

The above program is part of my ongoing investigation into topographically-enhanced mixing following completion of analysis of data collected over Fieberling Seamount under ONR's Topographic Interactions ARI. Turbulent mixing found atop Fieberling Seamount (Kunze and Toole 1997; Toole et al. 1997), although 100-1000 times higher than that in the ocean interior, is insufficient to dominate basin-wide mixing and close the proposed thermohaline circulation. This has motivated examination of other kinds of topography and mechanisms, in particular, tidal forcing. Polzin et al. (1997) found widespread elevated turbulence above the Mid-Atlantic Ridge that they propose is driven by tides. Tidally-driven mixing over Cobb Seamount (Lueck and Mudge 1997) and Mendocino Escarpment (Kunze and Sanford, personal communication) is comparable to that found above Fieberling Seamount. A multi-investigator observational and modelling program has been submitted to NSF to examine tidal mixing along the Hawaiian Ridge, which represents a much larger obstacle to the astronomical tides than topographic features that have been examined to date. While too early to be certain, existing evidence suggests that, except in abyssal waters, topographically-enhanced mixing is not large enough to close the global conveyor belt. This would leave surface mixing as the only viable candidate for waters between 1 and 3 kilometers depth in the temperate and equatorial oceans.

RELATED PROJECTS

The Virginia slope data will be compared with velocity, temperature and salinity profiles collected on the continental slope north of Monterey Bay on the west coast during August 1997 where several different topographic regimes are present. Preliminary analysis of the Monterey Slope data shows the presence of a narrow equatorward undercurrent hugging the slope with energetic near-inertial waves on the outer, negative vorticity side of the current. Horizontal energy-fluxes are alongslope, and appear to be generated by smallscale topographic features along the continental slope.

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